MEMCMR32CBUM/D
Rev. 1.0

Freescale Semiconductor, Inc.

Motorola Embedded Motion Control

MC68HC908MR32 Control Board

User's Manual

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1.2 Introduction

Motorola's MC68HC908MR32 motor control board is an integral part of the embedded motion control series of development tools. It interfaces easily with power stages, optoisolators, and emulators to complement software development tools for the MC68HC908MR32 (MR32).

The MR32 motor control board is supplied in kit number ECCTR908MR32. It is shipped along with a small printed circuit daughter board (SKT908MR32), an MR32, a 12-volt/4-amp power supply, mounting hardware, a 40-pin ribbon cable, and a CD ROM.

The MR32 motor control board is designed as an aid for hardware and software development of 3-phase ac induction, brushless dc (BLDC), and switched reluctance (SR) motor drives.

There are two modes of operation.

- The MR32 control board can be connected to an M68EM08MR32 emulator board, in an MMDS05/08 or MMEVS05/08 emulation system, through an M68CBL08A impedance-matched ribbon cable.
- Alternatively, the daughter board housing an HC908MR32 can be plugged into the control board in place of the emulator cable from the MMDS08.

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A few of the more noteworthy features are:

- Six motor control PWM outputs with LED indicators
- Speed control potentiometer
- Optoisolated half-duplex RS-232 interface
- Start/Stop and Forward/Reverse switches
- Hall effect inputs for brushless dc motor control
- Back EMF inputs for brushless dc motor control
- Tachometer input
- 2-position DIP switch for user option control
- Emulator/Daughter board connectors
- Processor reset switch
- Two system fault inputs
- Nine analog inputs
- Three softwarecontrolled LEDs
- Regulated on-board regulated power supply

The MR32 motor control board fits into the systems' configurations that are shown in **Figure 1-1**. A photograph of the control board with its daughter board attached appears in **Figure 1-2**.

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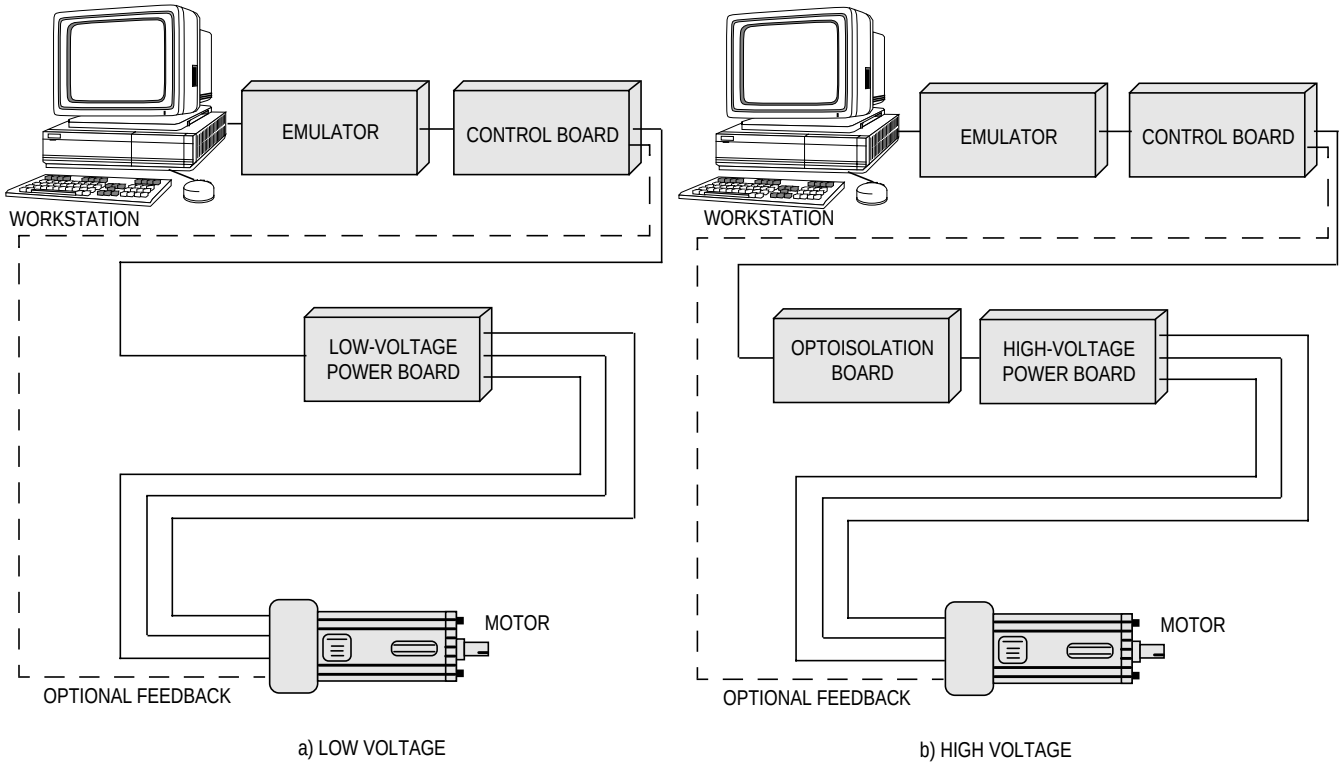

Figure 1-1. Systems' Configurations

1.3 About this Manual

Key items can be found in the following locations in this manual:

- Setup instructions are found in **1.5 Setup Guide**.
- Schematics are found in **4.3 Schematics**.
- Pin assignments are shown in **Figure 3-2. 40-Pin Ribbon Cable Connector J5**, and a pin-by-pin description is contained in **3.3 Control Board Signal Descriptions**.
- For those interested in the reference design aspects of the board's circuitry, a description is provided in **Section 5. Design Considerations**.

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1.4 Warnings

This development tool set operates in an environment that can include dangerous voltages and rotating machinery.

To facilitate safe operation, input power for high-voltage power stages should come from a current-limited dc laboratory power supply, unless power factor correction is specifically being investigated.

When operating high-voltage power stages directly from an ac line, power stage grounds and oscilloscope grounds are at different potentials, unless the oscilloscope is floating. Note that probe grounds and, therefore, the case of a floated oscilloscope, are subjected to dangerous voltages.

The user should be aware that:

- Before moving scope probes, making connections, etc., it is generally advisable to power down the high-voltage supply.
- When high voltage is applied to one of the high-voltage power stages, using only one hand for operating the test setup minimizes the possibility of electrical shock.
- Operation in labs with grounded tables and/or chairs should be avoided.
- Wearing safety glasses, avoiding ties and jewelry, using shields, and operation by personnel trained in high-voltage lab techniques are also advisable.

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1.5 Setup Guide

Setup and connections for the MR32 motor control board are very straightforward. Input connections to an M68EM08MR32 emulator are made through an M68CBL08A impedance-matched ribbon cable. Output connections to an embedded motion control optoisolation board or low-voltage power stage are made via a 40-pin ribbon cable that is supplied in the ECCTR908MR32 kit. The MR32 motor control board is powered through the 40-pin ribbon cable, regardless if it is connected to the optoisolation board or a low-voltage power stage. The included 12-volt/4-amp power supply provides power for either the optoisolation board or a low-voltage power stage. **Figure 1-3** shows parts locations, and **Figure 1-4** depicts a completed high-voltage setup.

A step-by-step procedure for setup with an optoisolator board and high-voltage power stage follows.

1. Mount four standoffs to the optoisolation board at the locations indicated in **Figure 1-4**. Standoffs, screws, and washers are included in the MR32 motor control board kit.
2. Plug one end of the 40-pin ribbon cable into the optoisolation board's input connector J2, labeled "Control Board." The 40-pin ribbon cable is also supplied in the MR32 motor control board kit.
3. Mount the control board on top of the standoffs.
4. Plug the free end of the 40-pin ribbon cable into the control board's output connector, J5, located on the right hand side of the board.
5. Plug the square end of an M68CBL08A emulator cable into the emulator cable connectors, J3 and J4, in the center of the board.
6. Plug the free end of the emulator cable into the emulator. If the emulator has not been set up, it will need to be connected to a PC and power source according to its setup instructions.
7. Locate START/STOP switch SW3 and set it to STOP.
8. Locate SPEED potentiometer, P1, and set it to the slowest speed by rotating P1 to its most counter clockwise position.
9. Locate forward (FWD) and reverse (REV) switch SW4 and set it to the desired direction of motor rotation.

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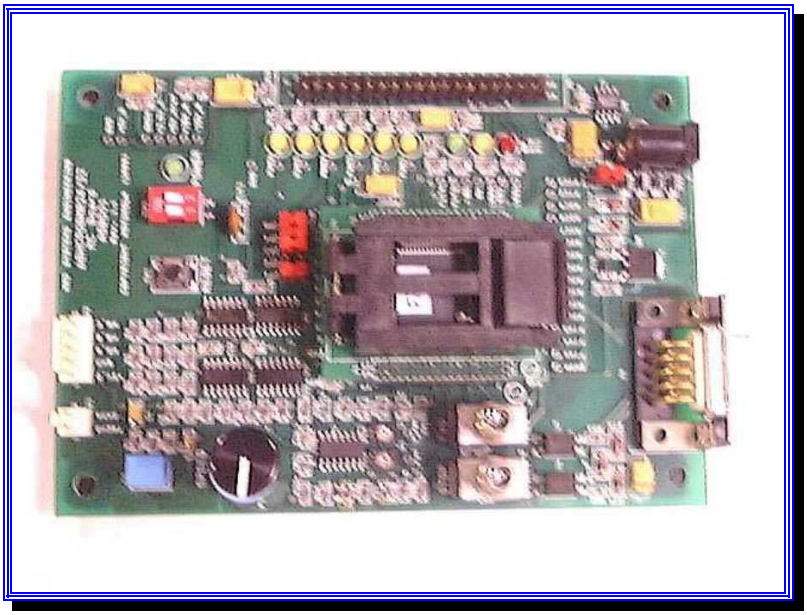

Figure 1-2. Control Board

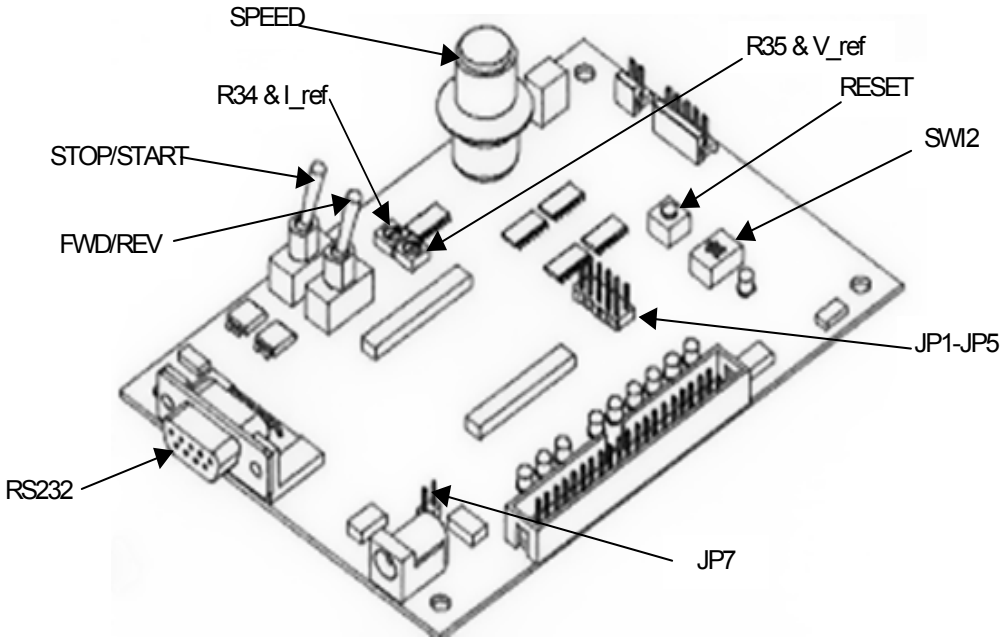

Figure 1-3. Setup Parts Locations

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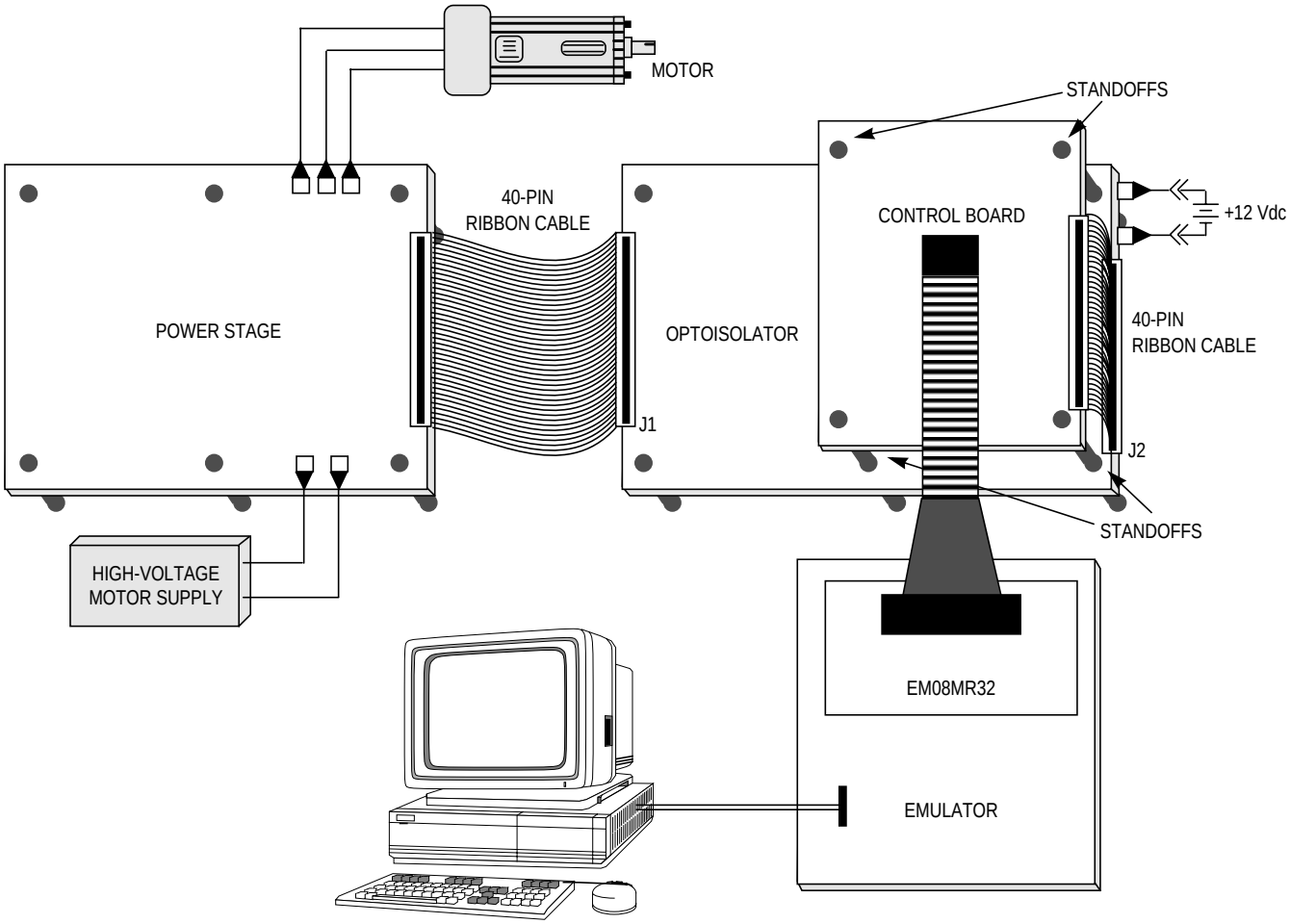

Figure 1-4. Setup for High-Voltage Systems

10. If an encoder, tachometer, back EMF signals, or the power factor correction (PFC) circuit are used, it is necessary to configure jumpers JP1–JP5. An “X” in **Table 1-1** indicates that the respective jumper should be shorted. The encoder and BEMF zero crossing signals are connected to the same timer channel (TCH2A). Therefore, do not short both JP2 and JP3.

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Table 1-1. Jumper JP1–JP5 Settings

Function	JP1 Tacho	JP2 Encoder	JP3 BEMF_z_c	JP4 PFC_z_c	JP5 PFC_PWM
Encoder		X			
Power factor correction				X	X
Tachometer	X				
Back EMF			X		

X = Short this jumper.

11. Switch SW2 and jumper JP6 can also be used for configuration. They are set up according to the requirements of the specific software package that is used.
12. Apply dc power to the optoisolation board.
13. Adjust R34 such that the voltage at test point I_ref matches the value indicated in **Table 1-2**. The ground reference is GND_A.
14. Adjust R35 such that the voltage at test point V_ref matches the value indicated in **Table 1-2**. The ground reference is GND_A.

Table 1-2. Overcurrent and Overvoltage Adjustments

Power Stage	Overcurrent Comparator U5B		Overvoltage Comparator U5C	
EVM motor board	R34	2.8 Vdc	R35	1.24 Vdc
Low-voltage BLDC power stage	R34	3.3 Vdc	R35	2.5 Vdc
Low-voltage SR power stage	R34	3.3 Vdc	R35	2.5 Vdc
High-voltage ac BLDC power stage	R34	3.3 Vdc	R35	3.07 Vdc
High-voltage SR power stage	R34	3.3 Vdc	R35	3.07 Vdc

15. Turn off power to the optoisolation board.
16. If a brushless dc motor is controlled with either Hall sensors or an encoder, plug the Hall sensor or encoder cable into Hall sensor / encoder connector J2.

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17. If a tachometer is used, plug it into tacho input connector J1.
18. If PC-Master software is used for real-time control of motor operation, it is necessary to set up RS-232 serial communication with a PC. To do this, connect a 9-conductor straight-through cable from the control board's DB-9 connector, J6, to the COM1 or COM2 serial port of the PC. PC serial ports are wired as DTE (data terminal equipment) and the control board serial communications interface (SCI) port is wired as DCE (data communications equipment). Therefore, a 9-conductor cable wired straight through must be used. ***Do NOT use a null modem cable.***
19. This completes control board setup.

If a low-voltage power stage is used, the setup procedure follows the same steps, with the low-voltage power stage substituted for the optoisolation board. For low-voltage systems, setup is depicted in **Figure 1-5**.

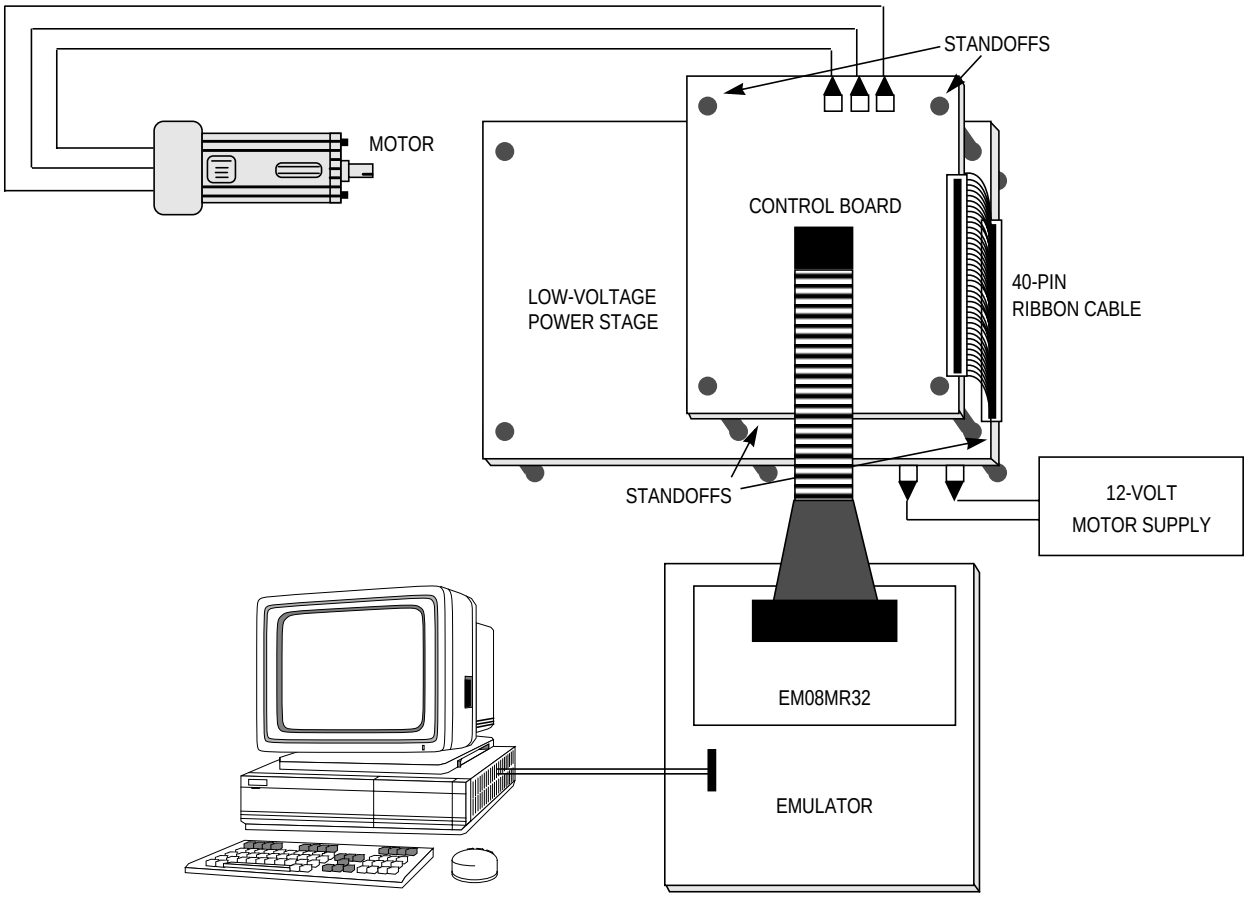

Figure 1-5. Setup for Low-Voltage Systems

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To switch from operation with the emulator to the daughter board, the following steps apply:

1. Rotate SPEED potentiometer, P1, counter clockwise to its slowest speed setting.
2. Remove power from the entire system (power stage, optoisolator, and emulator).
3. Remove the emulator cable from the control board.
4. Plug the daughter board into the emulator cable socket on the control board. Proper alignment is achieved when the number 1 in a circle on both boards in the vicinity of pins 1 and 2 are located in the same corner.
5. Program an MR32 microcontroller.
6. Insert the programmed microcontroller into its socket on the daughter board. Proper alignment is achieved when pin 1 of U1 is in the same corner of the socket as the 1 in a circle on the daughter board.
7. Restore power and resume operation.

It is also possible to use the MR32 motor control board by itself, without connection to any of the other embedded motion control series boards. To do so requires shorting jumper JP7 and plugging the 12-volt power supply into the power jack, J3.

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Section 2. Operational Description

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2.2 Introduction

Motorola's embedded motion control series MR32 motor control board is designed to provide control signals for 3-phase ac induction, 3-phase brushless dc (BLDC), and 3-phase switched reluctance (SR) motors. In combination with one of the embedded motion control series power stages, and an optoisolation board, it provides a software development platform that allows algorithms to be written and tested without the need to design and build hardware. With software supplied on the CD-ROM, the control board supports a wide variety of algorithms for ac induction, SR, and BLDC motors.

User control inputs are accepted from START/STOP, FWD/REV switches, and a SPEED potentiometer located on the control board. Alternately, motor commands can be entered via a PC and transmitted over a serial cable to DB-9 connector, J6. Output connections and power stage feedback signals are grouped together on 40-pin ribbon cable connector, J5. Motor feedback signals can be connected to Hall sensor/encoder connector J2. Power is supplied through the 40-pin ribbon cable from the optoisolation board or low-voltage power stage.

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Operational Description

The control board is designed to run in two configurations. It can be connected to an M68EM08MR32 emulator via an M68CBL08A impedance matched ribbon cable, or it can operate using the daughter board. The M68EM08MR32 emulator board may be used in either an MMDS05/08 or MMEVS05/08 emulation system. **Figure 2-1** shows a block diagram of the board's circuitry.

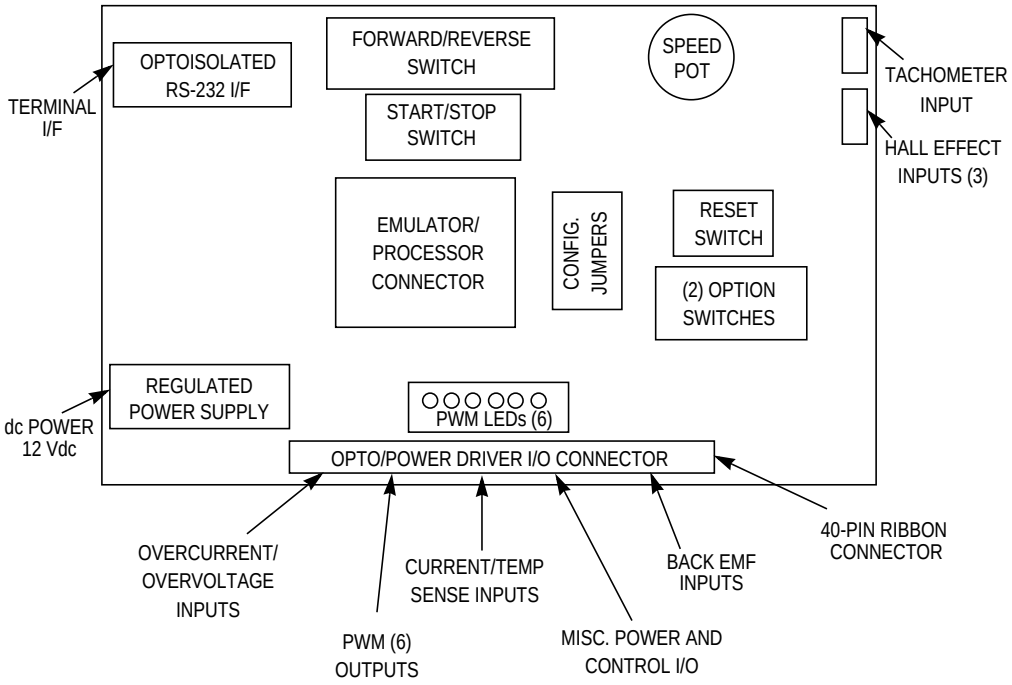

Figure 2-1. Block Diagram

A summary of the information needed to use the HC908MR32 motor control board is presented in the following sections. A discussion of the design appears in **Section 5. Design Considerations**.

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2.3 Electrical Characteristics

The electrical characteristics in **Table 2-1** apply to operation at 25°C.

Table 2-1. Electrical Characteristics

Characteristic	Symbol	Min	Typ	Max	Units
dc power supply voltage	Vdc	10.8*	12*	16.5*	V
Quiescent current	I_{CC}	—	80	—	mA
Min logic 1 input voltage (MR32)	V_{IH}	2.0	—	—	V
Max logic 0 input voltage (MR32)	V_{IL}	—	—	0.8	V
Propagation delay (Hall sensor/encoder input)	t_{dly}	—	—	500	ns
Analog input range	V_{In}	0	—	5.0	V
RS-232 connection speed		—	—	9600	Baud
PWM sink current	I_{PK}	—	—	20	mA

* When operated and powered separately from other Embedded Motion Control tool set products

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2.4 User Interfaces

There are five types of user interfaces on the HC908MR32 motor control board. They include an RS-232 serial interface, potentiometers, switches, jumpers, indicator lights, and test points. Descriptions of these interfaces follow.

2.4.1 Potentiometers

Three potentiometers (pot) provide for motor speed control, adjustment of the overcurrent fault threshold, and adjustment of the overvoltage fault threshold. They are:

- **P1: SPEED** — P1, labeled SPEED, is the speed control pot. Clockwise rotation increases motor speed. Speed control commands can also be sent over the RS-232 interface. At power-up and reset, speed control defaults to P1.
- **R34: Overcurrent Threshold** — The overcurrent fault threshold is set by trim pot R34. Clockwise rotation increases the threshold. Default settings for power stages in the embedded motion control tool set are found in **Table 1-2. Overcurrent and Overvoltage Adjustments**.
- **R35: Overvoltage Threshold** — The overvoltage fault threshold is set by trim pot R35. Clockwise rotation increases the threshold. Default settings for power stages in the embedded motion control tool set are found in **Table 1-2. Overcurrent and Overvoltage Adjustments**.

2.4.2 Switches

Four switches provide for user inputs. They are:

- **SW1: Reset** — SW1, the reset switch, is a push button located near the top of the board. It resets the 68HC908MR32.
- **SW2: DIP Switch SW2** — DIP switch SW2 contains two switches that are used for software configuration. They are set up according to the specific requirements of the software package used.
- **SW3: START/STOP** — SW3, START/STOP, is a toggle switch located on the left-hand side of the board. It starts and stops the motor. Up (toward the top of the board) turns the motor on and down stops it.

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- **SW4: FWD/REV** — SW4, FWD/REV, is a toggle switch located next to the START/STOP switch on the left side of the board. It controls direction of the motor. Up (toward the top of the board) runs the motor forward and down runs it in reverse.

2.4.3 Jumpers

There are seven jumpers, JP1–JP7. Jumpers JP1 through JP5 are located together near the center of the board above the emulator cable sockets. Jumper JP6 is located with switch SW2, and JP7 is in the lower left-hand corner of the board. They are:

- **JP1: Tacho** — Jumper JP1 is used to configure the board for a tachometer input. It is shorted when a tachometer is used.
- **JP2: Encoder** — Jumper JP2 is used to configure the board for an encoder input. It is shorted when an encoder is used. It should not be shorted when jumper JP3 is shorted.
- **JP3: BEMF_z_c** — Jumper JP3 is used to configure the board for back EMF signals. It is shorted when back EMF signals are used. It should not be shorted when jumper JP2 is shorted.
- **JP4: PFC_z_c** — Jumper JP4 is used to configure the board for power factor correction. It is shorted when set up for power factor correction (PFC).
- **JP5: PFC_PWM** — Jumper JP5 is also used to configure the board for PFC. It is shorted when set up for PFC.
- **JP6: Software Configuration** — Jumper JP6 can be used for software configuration. It is set up according to the specific requirements of the software package used.
- **JP7: Power Supply** — Jumper JP7 is shorted when power jack J3 is used for the power supply input. This configuration is used only when the HC908MR32 motor control board is operated by itself, without connection to any of the other embedded motion control series boards.

Looked at from a timer channel point of view, jumpers JP1–JP5 provide the options summarized in **Table 2-2**.

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Table 2-2. Timer Channel Configuration

Timer Channel	Jumper	Jumper Inserted	Jumper Removed
TCH0A	JP4	PFC zero crossing	Test point PTE4
TCH0B	JP5	PFC PWM	Test point PTE1
TCH1A			Test point PTE5
TCH1B			Test point PTE2
TCH2A	JP2	Encoder	Test point PTE6
	JP3	BEMF zero crossing	Test point PTE6
TCH3A	JP1	Tacho	Test point PTE7

NOTE: *The encoder and BEMF zero crossing signals are connected to the same timer channel (TCH2A). Therefore, both JP2 and JP3 should not be shorted.*

2.4.4 Indicator Lights

Ten LEDs located on the control board provide status information to the user. Power-on LED, D2, is located in the top right-hand quadrant of the board. The other nine indicator lights are lined up in a row to the left of 40-pin ribbon connector J5. Descriptions are:

- **D2: Power On** — D2, labeled POWER, lights when power is applied to the board.
- **D3: Phase A Top** — D3 lights when PWM signal phase A top is high.
- **D4: Phase A Bottom** — D4 lights when PWM signal phase A bottom is high.
- **D5: Phase B Top** — D5 lights when PWM signal phase B top is high.
- **D6: Phase B Bottom** — D6 lights when PWM signal phase B bottom is high.
- **D7: Phase C Top** — D7 lights when PWM signal phase C top is high.
- **D8: Phase C Bottom** — D8 lights when PWM signal phase C bottom is high.
- **D9: Run (Green)** — D9 lights when the motor is running.
- **D10: Ready (Yellow)** — D10 lights when the motor is ready to run, and blinks when a fault is imminent.
- **D11: Fault (Red)** — D11 lights when a fault has occurred.

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2.4.5 Test Points

A variety of test points, listed in **Table 2-3**, are provided to facilitate measurements with an oscilloscope.

Table 2-3. Test Points

Label	Location	Signal Name	Connected To
GND	Upper right corner	GND	Digital ground
+5V_D	Upper right corner	+5V_D	5-volt digital supply
GNDA	Upper right corner	GNDA	Analog ground
+3.3V_A	Upper right corner	+3.3V_A	3.3-volt analog supply
+5V_Aref	Upper right corner	+5V_A_ref	5-volt analog reference
+15V_A	Upper right corner	+12/15V_A	+12-volt to +15-volt analog supply
–15V_A	Upper right corner	–12/15V_A	–12-volt to –15-volt analog supply
I_ref	Above RUN/STOP Switch		Wiper of R34
V_ref	Above FWD/REV Switch		Wiper of R35
GND	Below power-on LED	GND	Digital ground
PWM1	Left of PWM indicator lights	PWM_AT	Connector J5, pin 1
PWM2	Left of PWM indicator lights	PWM_AB	Connector J5, pin 3
PWM3	Left of PWM indicator lights	PWM_BT	Connector J5, pin 5
PWM4	Left of PWM indicator lights	PWM_BB	Connector J5, pin 7
PWM5	Left of PWM indicator lights	PWM_CT	Connector J5, pin 9
PWM6	Left of PWM indicator lights	PWM_CB	Connector J5, pin 11
/IRQ	Above emulator connector		IRQ1/Vpp
PTE7	Above emulator connector		PTE7/TCH3A
PTE6	Above emulator connector		PTE6/THC2A
PTE5	Above emulator connector		PTE5/TCH1A
PTE4	Above emulator connector		PTE4/TCH0A
PTE3	Above emulator connector		PTE3/TCLKA
PTE2	Above emulator connector		PTE2/TCH1B
PTE1	Above emulator connector		PTE1/TCTCH0B
PTE0	Above emulator connector		PTE0/TCLKB

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Table 2-3. Test Points (Continued)

Label	Location	Signal Name	Connected To
GND	Above emulator connector	GND	Digital ground
+5V_D	Above emulator connector	+5V_D	5-volt digital supply
GNDA	Below emulator connector	GNDA	Analog ground
PTA0	Below emulator connector		PTA0
PTA4	Below emulator connector		PTA4
PTA5	Below emulator connector		PTA5
ADC0	Below emulator connector	Speed Control	Wiper of P1
ADC1	Below emulator connector	V_sense_DCB	Connector J5, pin 21
ADC2	Below emulator connector	I_sense_DCB	Connector J5, pin 22
ADC3	Below emulator connector	I_sense_A	Connector J5, pin 23
ADC4	Below emulator connector	I_sense_B	Connector J5, pin 24
ADC5	Below emulator connector	I_sense_C	Connector J5, pin 25
ADC6	Below emulator connector	Temp_sense	Connector J5, pin 26
ADC7	Below emulator connector	BEMF_sense_A	Connector J5, pin 38
ADC8	Below emulator connector	BEMF_sense_B	Connector J5, pin 39
ADC9	Below emulator connector	BEMF_sense_C	Connector J5, pin 40
PTC2	Below emulator connector		PTC2
PTC3	Below emulator connector		PTC3
FLT3	Left of status indicator lights		PTD2/FLT3
FLT4	Left of status indicator lights		PTD3/FLT4
OC	Left of status indicator lights	Overcurrent	Output of U5B
OV	Left of status indicator lights	Overvoltage	Output of U5C
D9	Left of ribbon connector J5	LED3	PTC6
D10	Left of ribbon connector J5	LED2	PTC5
D11	Left of ribbon connector J5	LED1	PTC4

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2.4.6 RS-232 Interface

An RS-232 interface is available via DB-9 connector J6. It connects to serial port COM1 or COM2 on a Windows-based PC and enables motor commands to be entered via PC Master software. At power up or reset, control defaults to speed control pot P1, START/STOP switch SW3, and FWD/REV switch SW4. Control is transferred to the serial interface on the receipt of a command entered via PC-Master software.

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Operational Description

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Section 3. Pin Descriptions

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3.2 Introduction

There are seven connectors on the control board, J1–J7. **Figure 3-1** illustrates locations for these connectors. They are:

- J1 — Tachometer input connector
- J2 — 5-pin Hall sensor and encoder connector
- J3 — 40-pin emulator connector
- J4 — 40-pin emulator connector
- J5 — 40-pin ribbon cable connector
- J6 — RS-232 DB-9 connector
- J7 — Power jack

Two connectors on the daughter board are labeled J1 and J2. They mate with connectors J3 and J4 on the control board.

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3.3 Control Board Signal Descriptions

The following subsections describe signals on control board connectors J1–J7.

3.3.1 Tacho Input Connector J1

Tacho input connector, J1, is a 2-pin connector that accepts inputs from an analog tachometer. This signal is conditioned with comparator U5A and through jumper JP1 provides an input to timer channel TCH3A. The schematic in **Figure 4-4. Control Board Schematic (Sheet 2)** shows J1 at the left-center of the page. Pin 1 carries the tachometer input signal, and pin 2 is connected to analog ground, GNDA.

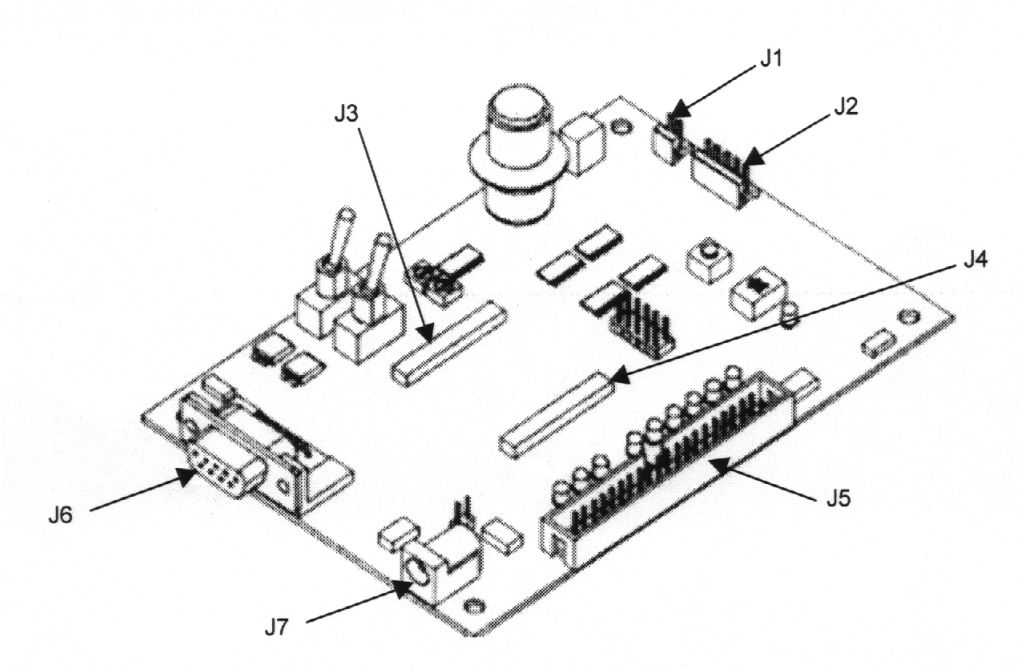

Figure 3-1. Connector Parts Locations

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3.3.2 Hall Sensor/Encoder Input Connector J2

The Hall sensor/encoder input connector, J2, is a 5-pin connector, which accepts input signals from Hall sensors or a quadrature encoder. Due to the likelihood of noise on Hall sensor inputs, these signals are filtered, and passed through a Schmitt trigger before being routed to logic circuitry. The schematic in **Figure 4-5. Control Board Schematic (Sheet 3)** shows J2 at the left-hand side of the page. The pinouts for a Hall sensor input are shown in **Table 3-1**.

Table 3-1. Hall Sensor Input

Pin No.	Signal Name	Description
1	+5V	+5V supplies power from the control board to the Hall sensors.
2	Gnd	Gnd is the Hall sensor ground.
3	Hall A	Hall A is an open collector output from Hall sensor A.
4	Hall B	Hall B is an open collector output from Hall sensor B.
5	Hall C	Hall C is an open collector output from Hall sensor C.

Pin assignments for quadrature encoder input are shown in **Table 3-2**.

Table 3-2. Quadrature Encoder Input

Pin No.	Signal Name	Description
1	+5V	Pin 1 supplies +5 volts from the control board to the encoder.
2	Gnd	Pin 1 is the encoder's ground.
3	Channel A	Pin 3 is the channel A input.
4	Channel B	Pin 4 is the channel B input.
5	Index	Pin 5 is the Index input.

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3.3.3 40-Pin Emulator Connector J3

Connectors J3 and J4 are 40-pin connectors which link signals between the control board and an MR32 emulator cable or daughter board. **Figure 4-2. Connectors J3 and J4** shows the pinouts and signal names. Signal descriptions for connector J3 are given in **Table 3-3**.

Table 3-3. Connector J3 Signal Descriptions

Pin No.	Signal Name	Description
1	I_sense_DCB (PTB2/ATD2)	An analog sense input signal that measures the power board's dc bus current
2	I_sense_A (PTB3/ATD3)	An analog sense input signal that measures the phase A current
3	GND	Digital power supply ground
4	I_sense_B (PTB4/ATD4)	An analog sense input signal that measures the phase B current
5	I_sense_C (PTB5/ATD5)	An analog sense input signal that measures the phase C current
6	Temp_sense (PTB6/TD6)	An analog sense input signal that measures power stage substrate temperature
7	BEMF_sense_A (PTB7/ATD7)	An analog sense input signal that measures the back EMF of phase A
8	GND	Digital power supply ground
9	BEMF_sense_B (PTC0/ATD8)	An analog sense input signal that measures the back EMF of phase B
10	BEMF_sense_C (PTC0/ATD8)	An analog sense input signal that measures the back EMF of phase C
11	Not used	
12	Not used	
13	Not used	
14	+5V_A_ref	+5V_A_ref is the A/D converter's reference voltage.
15	PTB0/ATD0	PTB0/ATD0 is derived from the wiper of the SPEED potentiometer, P1.
16	V_sense_DCB (PTB1/ATD1)	An analog sense input signal that measures the power board's dc bus voltage

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Table 3-3. Connector J3 Signal Descriptions (Continued)

Pin No.	Signal Name	Description
17	GND	Digital power supply ground
18	Brake (PTA7)	Brake is the gate drive signal for the power board's brake transistor.
19	PTA5	PTA5 is a digital signal from the START/STOP switch, SW3.
20	S_C (PTA6)	S_C is the serial communications signal used for power stage identification.
21	Not used	
22	PTA4	This is a digital signal from the FWD/REV switch, SW4.
23	(PTA1) Not used	
24	(PTA2) Not used	
25	(PTA0) Not used	
26	GND	Digital power supply ground
27	xEM_Vdda	xEM_Vdda is a filtered +5-volt power supply voltage that is derived from +5V_D.
28	GND	Digital power supply ground
29	Not used	
30	GNDA	Analog power supply ground
31	(Extra GND)	Extra digital power supply ground
32	Not used	
33	EM_RESET	EM_RESET is the reset signal from the RESET push-button switch SW1.
34	IRQ1/Vpp	IRQ1/Vpp is a connection from the MR32's IRQ1/Vpp pin through 10 kΩ to +5 volts.
35	TxD (PTF5/TxD)	TxD is an RS-232 serial communications signal transmitted from the MR32.
36	RxD (PTF4/RxD)	RxD is an RS-232 serial communications signal received by the MR32.
37	MUX_A (PTF3)	MUX_A is a multiplexed digital control signal for phase A used in the back EMF selection logic circuitry.
38	MUX_B (PTF2)	MUX_B is a multiplexed digital control signal for phase B used in the back EMF selection logic circuitry.
39	GND	Digital power supply ground
40	MUX_C (PTF1)	MUX_C is a multiplexed digital control signal for phase C used in the back EMF selection logic circuitry.

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3.3.4 40-Pin Emulator Connector J4

Signal descriptions for connector J4 are listed in **Table 3-4**.

Table 3-4. Connector J4 Signal Descriptions

Pin No.	Signal Name	Description
1	PTC2	Not used
2	GND	Digital power supply ground
3	PTC3	Not used
4	GND	Digital power supply ground
5	LED1 (PTC4)	LED1 is a digital signal that turns on the red (fault) LED when a fault is present.
6	GND	Digital power supply ground
7	LED2 (PTC5)	LED2 is a digital that controls the yellow (ready/warning) LED.
8	GND	Digital power supply ground
9	LED3 (PTC6)	LED3 is a digital signal that turns on the green (run) LED when the motor is running.
10	Overvoltage (PTD0/FAULT1)	Overvoltage is a digital input signal that indicates an overvoltage fault. This pin is at logic 1 when a fault is present.
11	Overcurrent (PTD1/FAULT2)	Overcurrent is a digital signal that indicates an overcurrent fault. This pin is at logic 1 when a fault is present.
12	GND	Digital power supply ground
13	GND	Digital power supply ground
14	+5V_D	+5V_D is the digital supply voltage.
15	FLT3	FLT3 is a digital signal that indicates a commutation error. A logic 1 indicates that a commutation fault occurred.
16	FLT4	FLT4 is a digital signal that indicates an overtemperature fault. This pin is at logic 1 when a fault is present.
17	Zero_Cross_A (PTD4/IS1)	Zero_Cross_A is a digital signal used for sensing phase A back EMF zero crossing events.
18	Zero_Cross_B (PTD5/IS2)	Zero_Cross_B is a digital signal used for sensing phase B back EMF zero crossing events.
19	Zero_Cross_C (PTD6/IS3)	Zero_Cross_C is a digital signal used for sensing phase C back EMF zero crossing events.

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Table 3-4. Connector J4 Signal Descriptions (Continued)

Pin No.	Signal Name	Description
20	GND	Digital power supply ground
21	PWM2	PWM2 is the gate drive signal for the bottom half-bridge of phase A.
22	PWM1	PWM1 is the gate drive signal for the top half-bridge of phase A.
23	PWM4	PWM4 is the gate drive signal for the bottom half-bridge of phase B.
24	PWM3	PWM3 is the gate drive signal for the top half-bridge of phase B.
25	PWM5	PWM5 is the gate drive signal for the top half-bridge of phase C.
26	PWMGND	PWMGND is the PWM timer's ground. It is tied to digital power supply ground, GND.
27	GND	Digital power supply ground
28	PWM6	PWM6 is the gate drive signal for the bottom half-bridge of phase C.
29	PTE1/TCTCH0B	When jumper JP5 is shorted, PTE1/TCTCH0B is the power factor correction circuit's gate drive signal, PFC_PWM.
30	PTE0/TCLKB	Not used
31	PTE3/TCLKA	Not used
32	PTE2/TCH1B	Not used
33	PTE4/TCH0A	When jumper JP4 is shorted, PTE4/TCH0A is the power factor correction circuit's zero crossing signal, PFC_z_c.
34	GND	Digital power supply ground
35	PTE6/TCH2A	When jumper JP2 is shorted, PTE6/TCH2A is the encoder signal from the output of the encoder/Hall sensor XOR logic circuit, U4B. When jumper JP3 is shorted, PTE6/TCH2A is the power factor correction circuit's zero crossing signal, PFC_z_c.
36	PTE5/TCH1A	Not used
37	+5V_D	+5V_D is the 5-volt digital power supply.
38	PTE7/TCH3A	When jumper JP1 is shorted, the PTE7/TCH3A is the tacho digital output signal from U5A.
39	PFC_inhibit (PTF0/SPSCK)	PFC_inhibit is a digital output from the microcontroller used to enable or disable the power factor correction circuit.
40	Not used	

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3.3.5 40-Pin Connector J5

Signals to and from a power stage are grouped together on 40-pin ribbon cable connector J5. Pin assignments are shown in **Figure 3-2**. In this figure, a schematic representation appears on the left, and a physical layout of the connector appears on the right. The physical view assumes that the board is oriented such that its title is read from left to right. See **Table 3-5**.

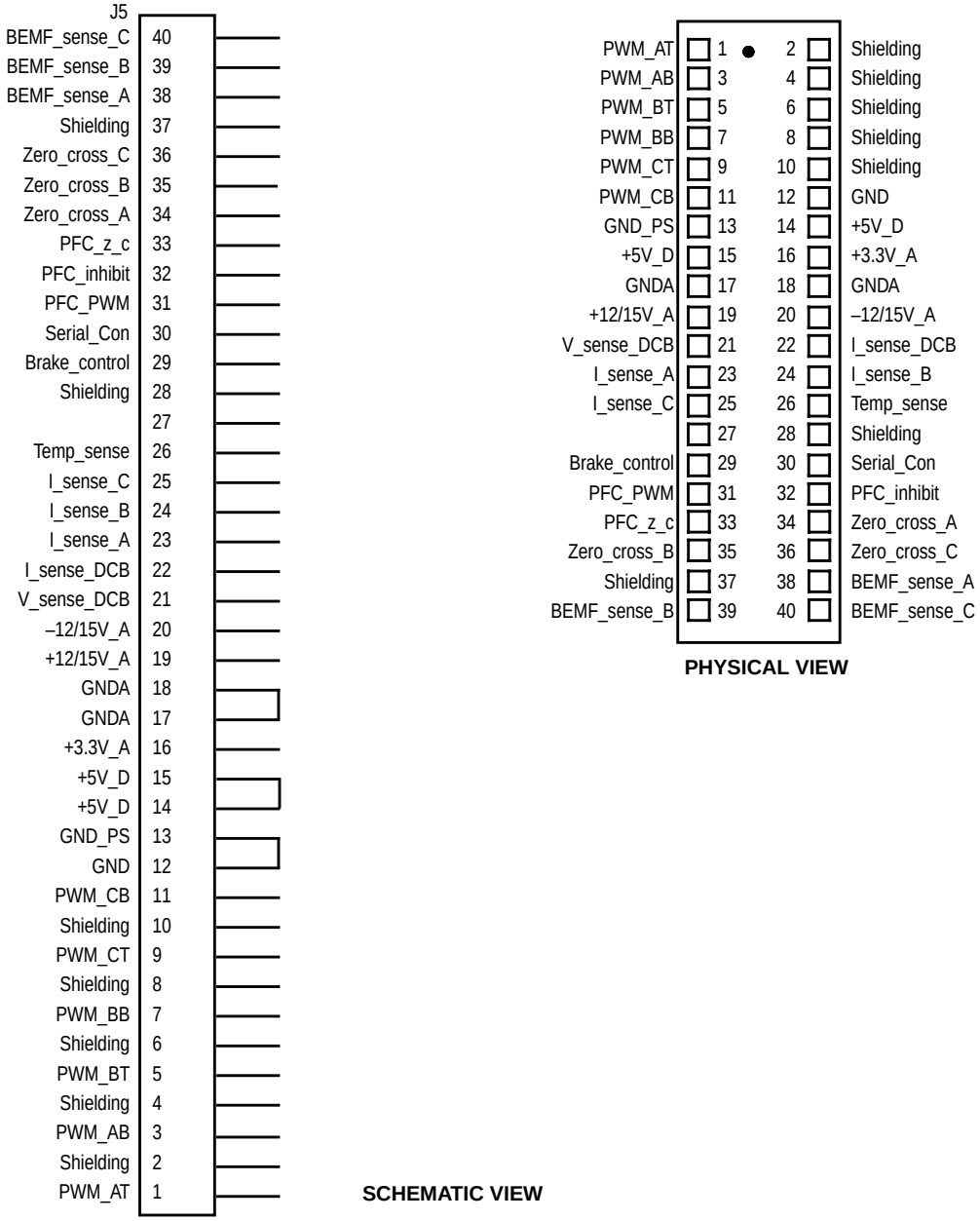

Figure 3-2. 40-Pin Ribbon Cable Connector J5

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Table 3-5. Connector J5 Signal Descriptions (Sheet 1 of 3)

Pin No.	Signal Name	Description
1	PWM_AT	PWM_AT is the gate drive signal for the top half-bridge of phase A. A logic high turns phase A's top switch on.
2	Shielding	Pin 2 is connected to an unused wire that helps prevent cross talk between adjacent signals.
3	PWM_AB	PWM_AB is the gate drive signal for the bottom half-bridge of phase A. A logic high turns on phase A's bottom switch.
4	Shielding	Pin 4 is connected to an unused wire that helps prevent cross talk between adjacent signals.
5	PWM_BT	PWM_BT is the gate drive signal for the top half-bridge of phase B. A logic high turns on phase B's top switch.
6	Shielding	Pin 6 is connected to an unused wire that helps prevent cross talk between adjacent signals.
7	PWM_BB	PWM_BB is the gate drive signal for the bottom half-bridge of phase B. A logic high turns on phase B's bottom switch.
8	Shielding	Pin 8 is connected to an unused wire that helps prevent cross talk between adjacent signals.
9	PWM_CT	PWM_CT is the gate drive signal for the top half-bridge of phase C. A logic high turns on phase C's top switch.
10	Shielding	Pin 10 is connected to an unused wire that helps prevent cross talk between adjacent signals.
11	PWM_CB	PWM_CB is the gate drive signal for the bottom half-bridge of phase C. A logic high turns on phase C's bottom switch.
12	GND	Digital power supply ground
13	GND	Digital power supply ground, redundant connection
14	+5V digital	Digital +5-volt power supply
15	+5V digital	Digital +5-volt power supply, redundant connection
16	+3.3V analog	Analog +3.3-volt power supply
17	GNDA	Analog power supply ground
18	GNDA	Analog power supply ground, redundant connection
19	+12/15V_A	Analog +12-volt to +15-volt power supply. +12 volts is supplied from low-voltage power stages. +15 volts is supplied from the optoisolation board and high-voltage power stages.

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Pin Descriptions

Table 3-5. Connector J5 Signal Descriptions (Sheet 2 of 3)

Pin No.	Signal Name	Description
20	–12/15V_A	Analog –12-volt to –15-volt power supply. –12 volts are supplied from low-voltage power stages. –15 volts are supplied from the optoisolation board and high-voltage power stages.
21	V_sense_DCB	V_sense_DCB is an analog sense signal that measures the power board's dc bus voltage.
22	I_sense_DCB	I_sense_DCB is an analog sense signal that measures the power board's dc bus current.
23	I_sense_A	I_sense_A is an analog sense signal that measures current in phase A.
24	I_sense_B	I_sense_B is an analog sense signal that measures current in phase B.
25	I_sense_C	I_sense_C is an analog sense signal that measures current in phase C.
26	Temp_sense	Temp_sense is an analog sense signal that measures the power stage's substrate temperature.
27	Shielding	Pin 27 is connected to an unused wire that helps prevent cross talk between adjacent signals.
28	Shielding	Pin 28 is connected to an unused wire that helps prevent cross talk between adjacent signals.
29	Brake_control	Brake_control is the gate drive signal for the power board's brake transistor.
30	Serial_Con	Serial_Con is a bidirectional digital serial interface used to identify the power board to the control board. This information is then used by the control board's software to scale analog feedback signals.
31	PFC_PWM	PFC_PWM is the power factor correction circuit's gate drive signal.
32	PFC_inhibit	PFC_inhibit is a digital output from the microcontroller, U1, that is used to enable or disable the power factor correction circuit.
33	PFC_z_c	PFC_z_c is the power factor correction circuit's zero crossing signal.
34	Zero_cross_A	Zero_cross_A is a digital signal that is used for sensing phase A back-EMF zero crossing events.
35	Zero_cross_B	Zero_cross_B is a digital signal that is used for sensing phase B back-EMF zero crossing events.
36	Zero_cross_C	Zero_cross_C is a digital signal that is used for sensing phase C back-EMF zero crossing events.
37	Shielding	Pin 37 is connected to an unused wire that helps prevent cross talk between adjacent signals.
38	BEMF_sense_A	BEMF_sense_A is an analog sense signal that measures phase A back EMF.

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Table 3-5. Connector J5 Signal Descriptions (Sheet 3 of 3)

Pin No.	Signal Name	Description
39	BEMF_sense_B	BEMF_sense_B is an analog sense signal that measures phase B back EMF.
40	BEMF_sense_C	BEMF_sense_C is an analog sense signal that measures phase C back EMF.

3.3.6 RS-232 DB-9 Connector J6

The RS-232 DB-9 connector, J6, is a 9-pin female connector for serial communications with a PC. It has standard RS-232 pinouts. The schematic in **Figure 4-4. Control Board Schematic (Sheet 2)** shows J6 at the top-center of the page. Signal descriptions are listed in **Table 3-6**:

Table 3-6. Connector J6 Signal Descriptions

Pin No.	Signal Name	Description
1	Unused	N/A
2	RXD	Data received by the PC from the control board
3	TXD	Data transmitted from the PC to the control board
4	DTR	PC indicates that it is ready to receive data
5	GND	Common ground reference
6	Unused	N/A
7	RTS	PC requests to send data to the control board
8	Unused	N/A
9	Unused	N/A

3.3.7 Power Connector J7

A power connector, J7, is a 2.1-mm power jack provided for connection to the 12-volt power supply included in the HC908MR32 motor control board kit. This power input connector is used only when the control board is operating independently from other boards in the embedded motion control tool set.

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3.4 Daughter Board Signal Descriptions

Pin assignments for daughter board connectors J1 and J2 are identified as follows.

3.4.1 Daughter Board Connector J1

Daughter board 40-pin connector J1 mates with control board connector J3. Pin assignments for both connectors are identical. See **Table 3-3**.

3.4.2 Daughter Board Connector J2

Daughter board 40-pin connector J2 mates with control board connector J4. Pin assignments for both connectors are identical. See **Table 3-4**.

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Section 4. Schematics and Parts List

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4.2 Overview

A set of schematics for the control and daughter boards appear in **Figure 4-1** through **Figure 4-5**. **Figure 4-1** shows how the 68HC098MR32's pinouts match signal names on the control board. **Figure 4-2** depicts the two 40-pin connector connections that are made with either the daughter board or emulator cable. **Figure 4-3** through **Figure 4-5** show the control board's circuitry.

Unless otherwise specified, resistor values are in ohms, resistors are specified as 1/8-watt ± 5%, and interrupted lines coded with the same letters are electrically connected.

Parts lists for the control and daughter boards appear in **Table 4-1** and **Table 4-2**.

4.3 Schematics

Schematics for the control and daughter boards appear on the following pages.

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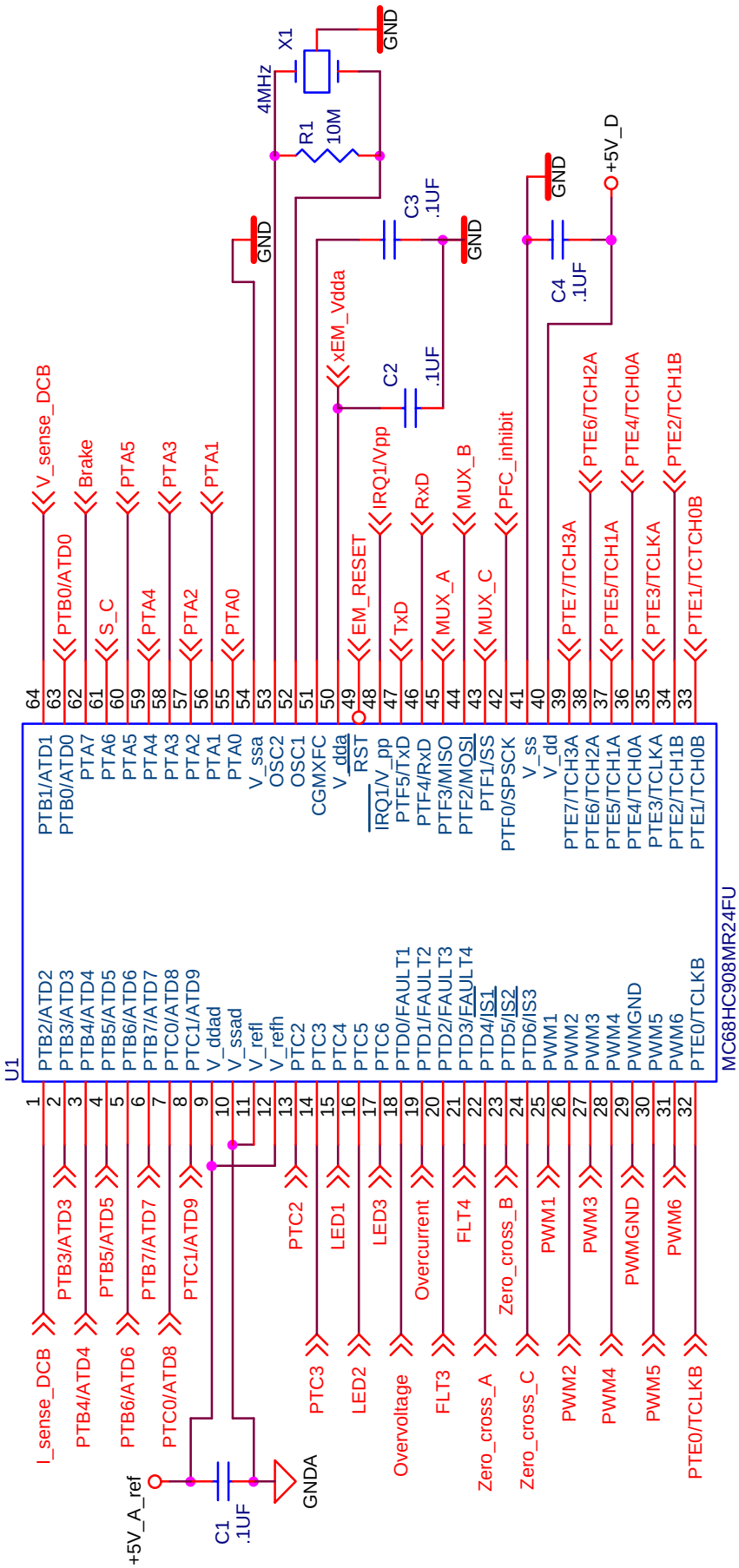

Figure 4-1. Daughter Board

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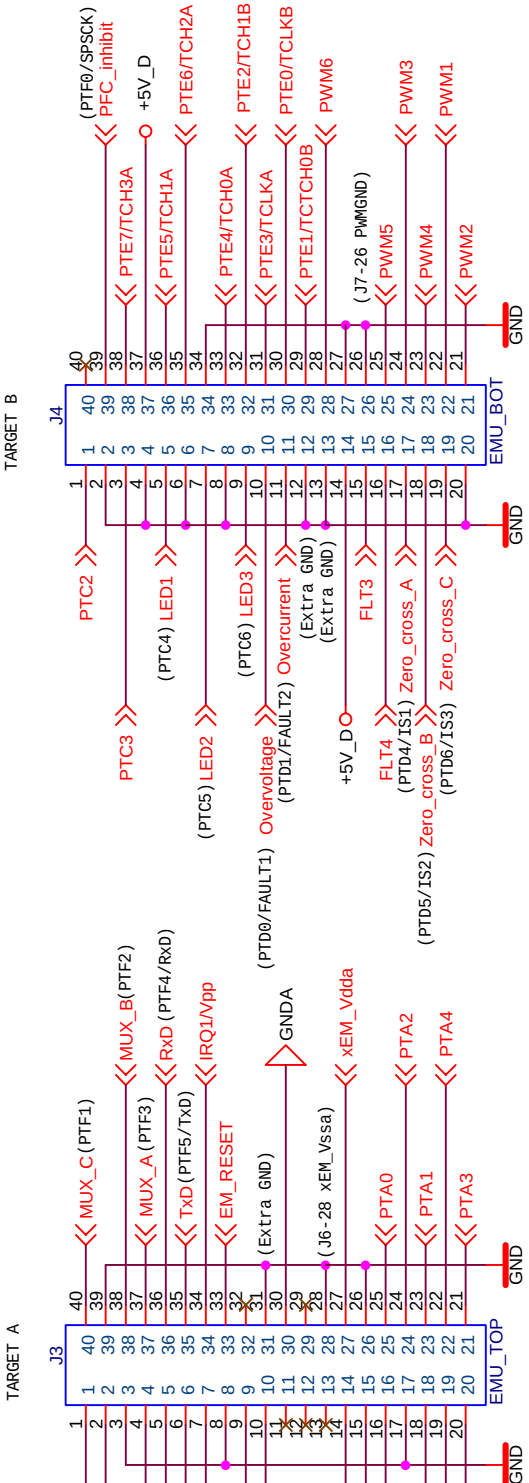

Figure 4-2. Connectors J3 & J4

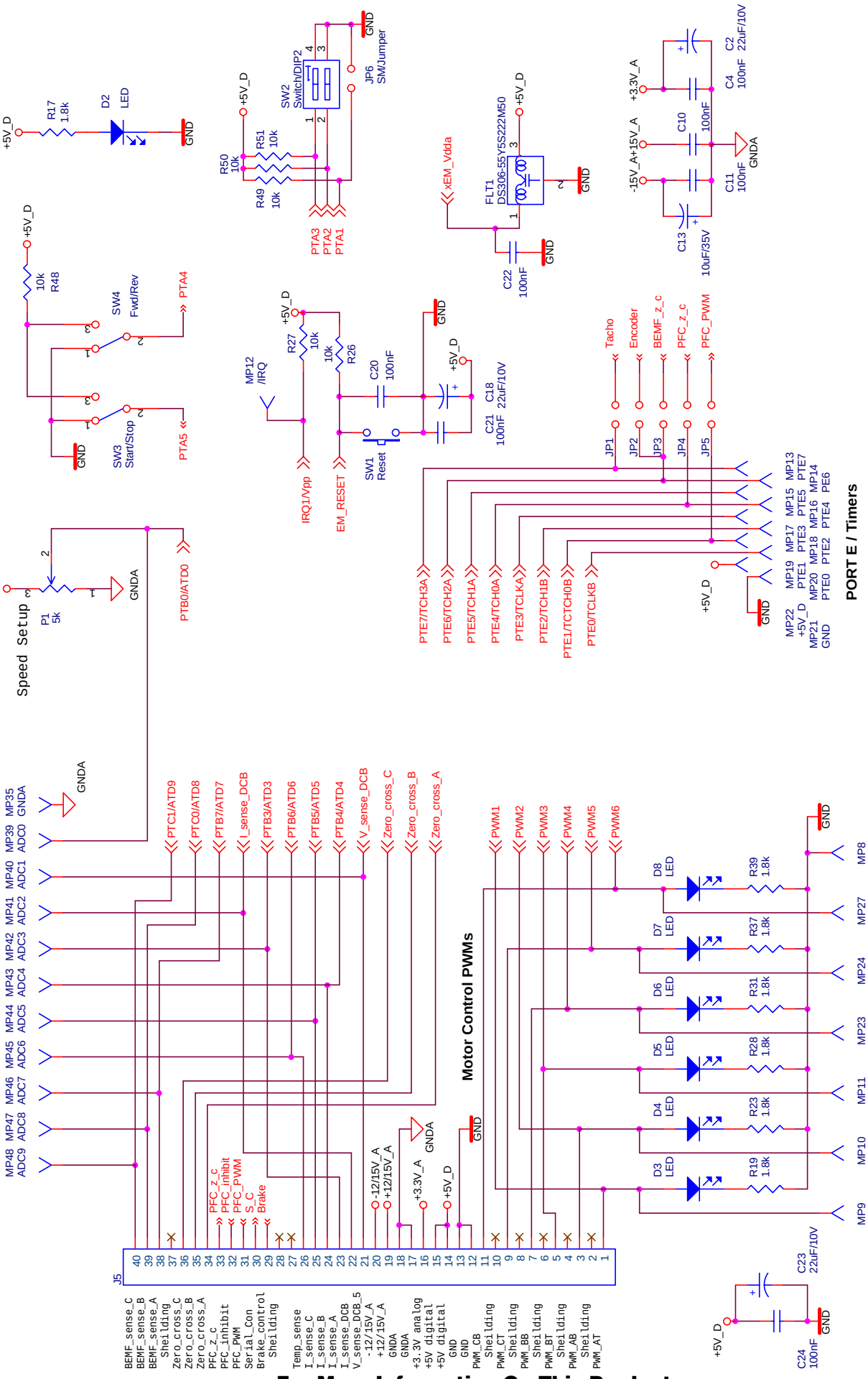

Figure 4-3. Control Board Circuitry (Sheet 1 of 3)

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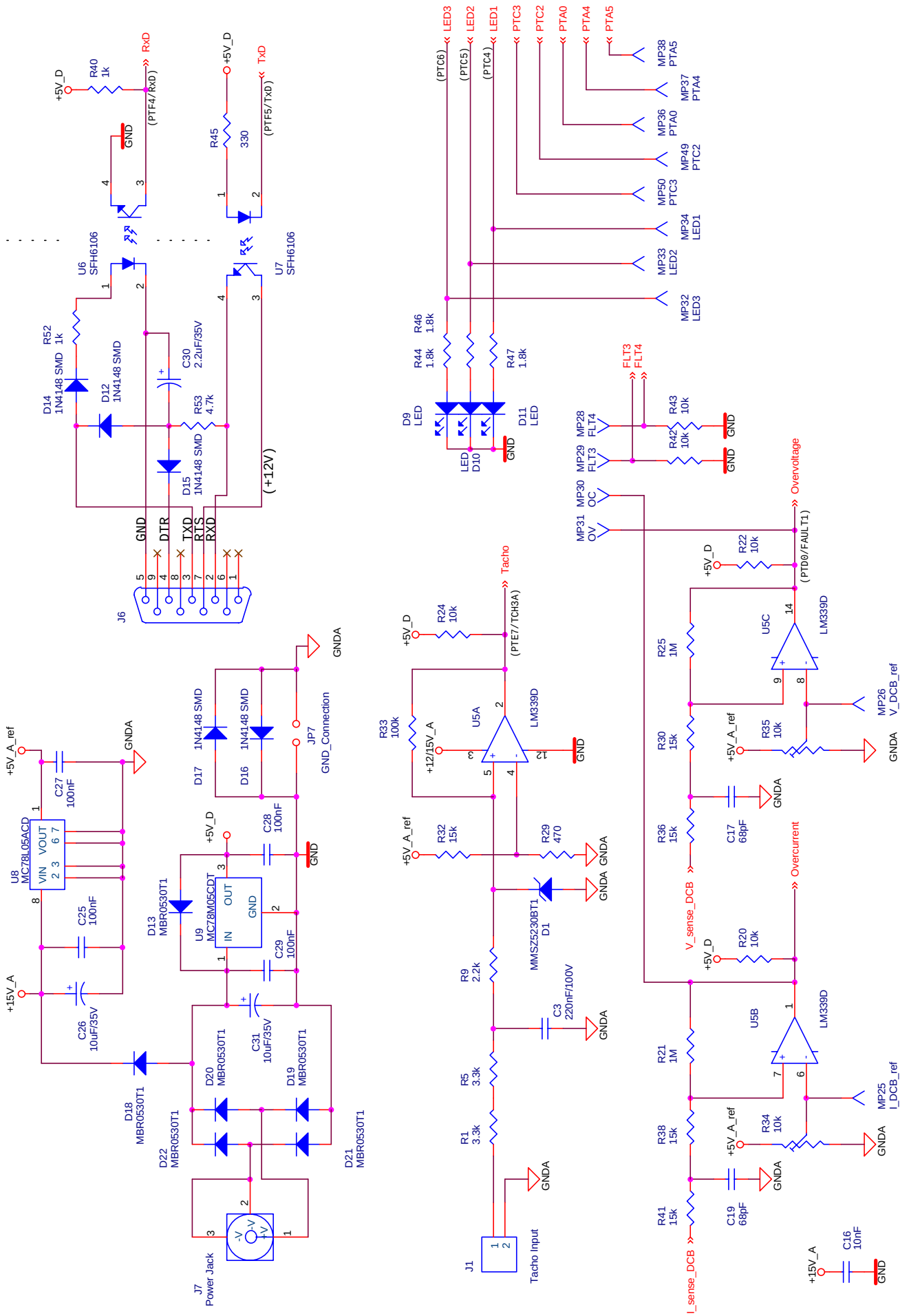

Figure 4-4. Control Board Circuitry (Sheet 2 of 3)

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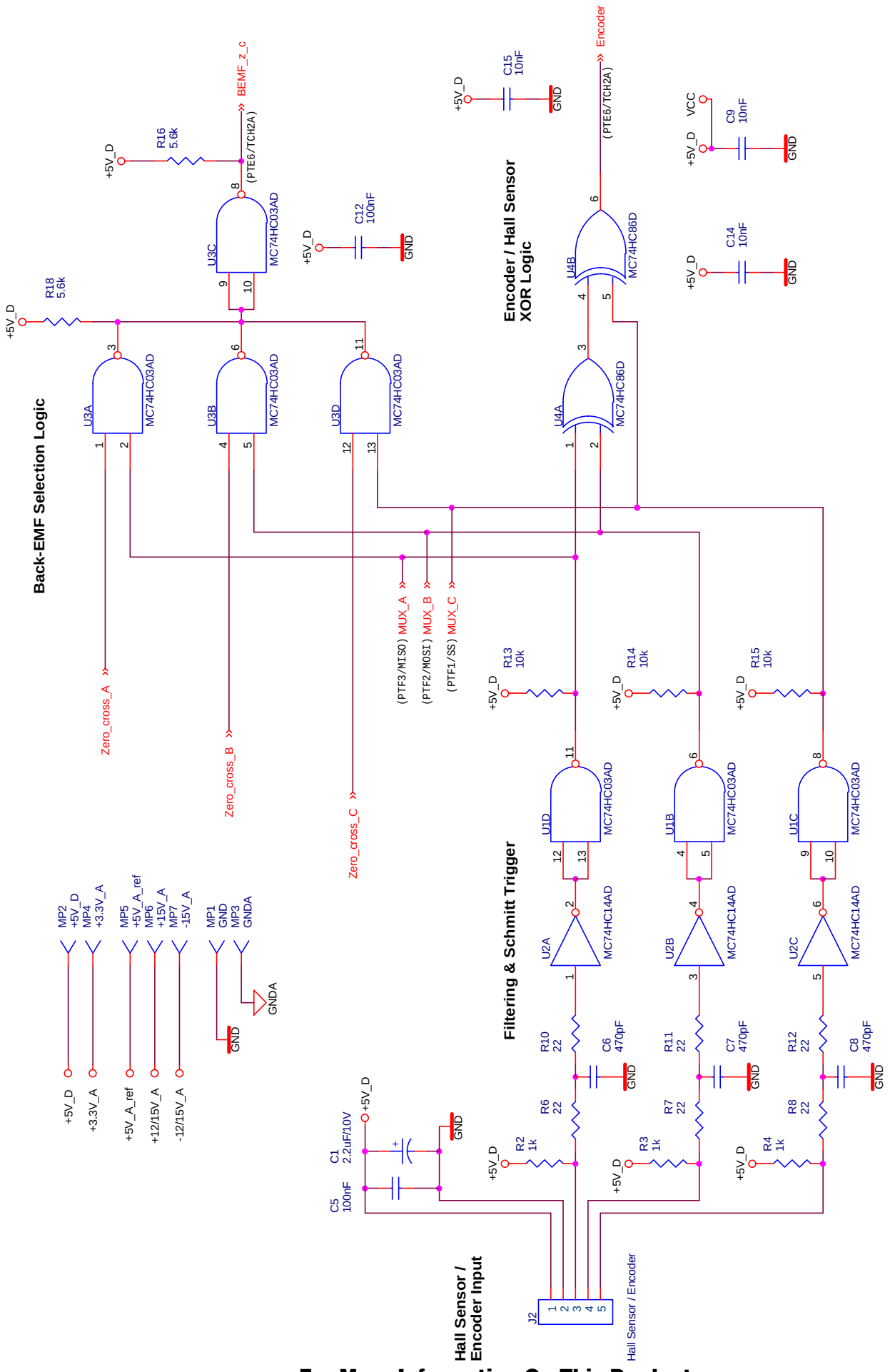

Figure 4-5. Control Board Circuitry (Sheet 3 of 3)

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4.4 Parts Lists

The following two parts lists describe parts content for the control and daughter boards.

Table 4-1. Control Board Parts List

Designators	Qty	Description	Manufacturer	Part Number
C1	1	2.2 µF/10 Vdc tantalum	Panasonic	ECS-T1AY225R
C2, C18, C23	3	22 µF/10 Vdc tantalum	Panasonic	ECS-T1AC226R
C3	1	220 nF/63 Vdc polyester	Philips/BC	2222 370 12224
C4, C5, C10, C11, C12, C20, C21, C22, C24, C25, C27, C28, C29	13	100 nF/50 Vdc ceramic	Panasonic	ECJ-2VF1H104Z
C6, C7, C8	3	470 pF/50 Vdc ceramic	Panasonic	ECU-V1H471JCX
C9, C14, C15, C16	4	10 nF/50 Vdc ceramic	Panasonic	ECJ-2VF1H103Z
C13, C26, C31	3	10 µF/35 Vdc tantalum	Panasonic	ECS-T1VD106R
C17, C19	2	68 pF/50 Vdc ceramic	Panasonic	ECU-V1H680JCG
C30	1	2.2 µF/35 Vdc tantalum	Panasonic	ECS-H1VC225R
D1	1	Zener diode, 4.7 V	ON Semiconductor	MMSZ5230BT1
D3–D8, D10	7	LED, yellow, 2 mA, 3 mm	Kingbright	L-934LYD
D11	1	LED, red, 2 mA, 3 mm	Kingbright	L-934LID
D2, D9	2	LED, green, 2 mA, 3 mm	Kingbright	L-934LGD
D12, D14–D17	5	1N4148	Vishay	LL4148
D13, D18–D22	6	Schottky diode	ON Semiconductor	MBR0530T1
FLT1	1	Filter	muRata	DS306-55Y5S222M50
JP1–JP5	1	Jumper 2x5 x.1oc	Berg Electronics	67997-210H
JP7	1	Jumper 2x1 x.1oc	Berg Electronics	67997-202H
J1	1	Connector, tacho input, 2-pin	AMP	MTA-100-640456-2

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Schematics and Parts List

Table 4-1. Control Board Parts List (Continued)

Designators	Qty	Description	Manufacturer	Part Number
J2	1	Connector, Hall input, 5-pin	AMP	MTA-100-640456-5
J3, J4	2	2x20-pin connector (male)	Berg Electronics	89465-120
J5	1	UNI 2x20x.1" shrouded	3M	2540-6002UB
J6	1	DB-9 connector	Keltron	DNR-09SCJB-SG
J7	1	Power connector	Switchcraft	RAPC722
P1	1	Potentiometer 5 k	Clarostat Sensors and Controls, Inc.	392-JA-502
R1, R5	2	3.3 kΩ resistor 1/10W 5% 0805	Any acceptable	
R2, R3, R4, R40, R52	5	1 kΩ resistor 1/10W 5% 0805	Any acceptable	
R6, R7, R8, R10, R11, R12	6	22 Ω resistor 1/10W 5% 0805	Any acceptable	
R9	1	2.2 kΩ resistor 1/10W 5% 0805	Any acceptable	
R13, R14, R15, R20, R22, R24, R26, R27, R42, R43, R48–R51	14	10 kΩ resistor 1/10W 5% 0805	Any acceptable	
R16, R18	2	5.6 kΩ resistor 1/10W 5% 0805	Any acceptable	

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Table 4-2. Daughter Board Parts List

Designators	Qty	Description	Manufacturer	Part Number
R17, R19, R23, R28, R31, R37, R39, R44, R46, R47	10	1.8 kΩ resistor 1/10W 5% 0805	Any acceptable	
R21, R25	1	1 MΩ resistor 1/10W 5% 0805	Any acceptable	
R29	1	560 Ω (was 470 Ω) resistor 1/10W 5% 0805	Any acceptable	
R30, R32, R36, R38, R41	5	15 kΩ resistor 1/10W 5% 0805	Any acceptable	
R33	1	330 kΩ (was 100 kΩ) resistor 1/10W 5% 0805	Any acceptable	
R45	1	330 Ω resistor 1/10W 5% 0805	Any acceptable	
R53	1	4.7 kΩ resistor 1/10W 5% 0805	Any acceptable	
R34, R35	2	10 kΩ SMT trimmer	Bourns	3364W-1-103E
SW1	1	Push-button switch	NKK Switches	CB15FP
SW2	1	2-position DIP switch	CTS	206-2
SW3, SW4	2	SPDT toggle switch	NKK Switches	M2012SS1G03
U1, U3	2	Quad NAND-open collector	ON Semi	MC74HC03AD
U2	1	Quad Schmitt trigger	ON Semi	MC74HC14AD
U4	1	Quad exclusive OR	ON Semi	MC74HC86AD
U5	1	Quad comparator	ON Semi	LM339D
U6, U7	2	Opto coupler	Siemens	SFH6106
U8	1	Voltage regulator	ON Semi	MC78L05ACD
U9	1	Voltage regulator	ON Semi	MC78M05CDT
Install on JP1, JP2, JP4, JP5, JP7	5	Shunt	Specialty Electronics	2JM-G
No designator	1	Knob for P1	Thomas & Bates	PKG-40B-1/8
No designator	5	Stick-on rubber feet	Fastex	5033-01-00-5001

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Table 4-2. Daughter Board Parts List (Continued)

Designators	Qty	Description	Manufacturer	Part Number
C1, C2, C3, C4	4	0.1UF cap 25 Vdc 0805	Digi-Key	PCC1828CT-ND
J1, J2	2	2x20-pin connector (female)	Berg	87012-620
R1	1	10 MΩ resistor 1/10W 0805	Digi-Key	P10MGCT-ND
U1	1	Microprocessor 68HC908MR32	Motorola	68HC908MR32CFU
X1	1	Ceramic resonator 4 MHz	muRata	CSTCC4.00MG
XU1	1	Socket for U1	Enplas	FPQ-64-0.8-02

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Section 5. Design Considerations

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5.8 Fault Circuits 56
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5.2 Overview

Motor drive systems have a number of important design considerations related to noise management and protection of the power transistors. They include noise management of Hall sensor inputs, simultaneous conduction lockout, dead time, power-up/power-down, and grounding.

These design considerations are discussed in **5.3 Sensor Inputs** through **5.7 Grounding**. A description of some of the control board's circuits is included in **5.8 Fault Circuits** through **5.11 Back EMF Signals**.

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5.3 Sensor Inputs

For brushless motors that use Hall sensor inputs for commutation, noise immunity of the sensor inputs is a key design consideration. Noise on these inputs can be particularly troublesome, since commutating to the wrong state precludes smooth operation of the motor. To facilitate noise robust sensor inputs, Schmitt triggers have been placed between the Hall sensor input connector and the processor. Schmitt triggers improve noise immunity by adding hysteresis to the signal paths. In addition, the sensor inputs are filtered with 100-ns single-pole filters, as shown in **Figure 5-1**. Using relatively low value pullup resistors, on the order of 1 kΩ, provides an additional measure of noise immunity.

How the code is written also has an important influence on noise robustness. Since the sequence of commutation is known, based upon the state of the forward/reverse input, it is relatively easy to detect an out-of-sequence Hall sensor input. Generally, when this occurs it is desirable to turn off all the power transistors until a valid Hall code is received.

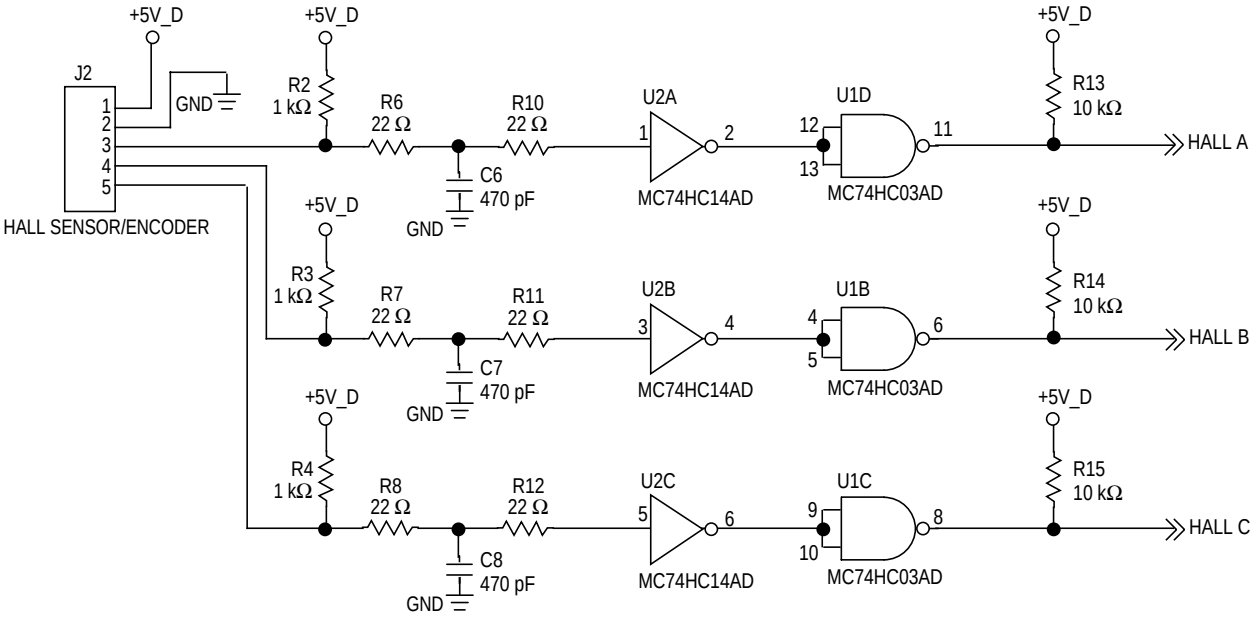

Figure 5-1. Hall Sensor Inputs

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5.4 Simultaneous Conduction Lockout

Especially on a machine that will be used for software development, it is desirable to prevent simultaneous conduction of upper and lower power transistors in the same phase. This feature is built into the 68HC908MMR32's PWM module. Once the PWM module has been initialized correctly, simultaneous conduction of a top and bottom output transistor in the same phase is locked out. Software errors that occur after initialization is completed will, therefore, not destroy power stage output transistors by turning on the top and bottom of one-half bridge simultaneously. This feature also prevents simultaneous conduction in the event of a noise-induced software runaway.

5.5 Dead Time

In Induction motor drives, providing dead time between turn-off of one output transistor and turn-on of the other output transistor in the same phase is an important design consideration. Dead time is also a feature that is built into the 68HC908MR32's PWM module. It is programmable to accommodate a variety of gate drives and output transistors. In this tool set, 2 µs of dead time has been selected for operation with the high-voltage power stages.

5.6 Power-Up/Power-Down

When power is applied or removed, it is important that top and bottom output transistors in the same phase are not turned on simultaneously. Since logic states are not always defined during power-up, it is important to ensure that all power transistors remain off when the controller's supply voltage is below its normal operating level. The 68HC908MR32's PWM module outputs make this easy by switching to a high-impedance configuration whenever the 5-volt supply is below its specified minimum.

The embedded motion control tool set's power boards have pull-down resistors at all of the gate drive inputs. This feature, coupled with the 68HC908MR32 PWM module's outputs, ensures that all power transistors remain off during power-up and power-down.

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5.7 Grounding

Board layout is an important design consideration. In particular, ground planes and how grounds are tied together influence noise immunity. In order to maximize noise immunity, it is important to get a good ground plane under the 68HC908MR32. Because it is also important to separate analog and digital grounds, there are two ground designations, GND and GNDA. GND is the digital ground plane and power supply return and GNDA is the analog circuit ground. They are both the same reference voltage, but are routed separately, and tie together at only one point.

In a design that uses the MR32's PWM outputs to directly drive opto couplers, it is also a good idea to section the digital ground plane around the PWM module's outputs. That way the relatively high return current associated with the PWM outputs does not flow all over the board.

5.8 Fault Circuits

Two fault signals are generated from analog bus current and bus voltage feedback signals, I_sense_DCB and V_sense_DCB. These analog signals are fed into comparators that have adjustable reference voltages, as shown in **Figure 5-2**.

The comparator outputs provide digital signals to the MR32's FAULT 1 and FAULT 2 inputs, respectively. Should one or both occur, these faults will force the PWM module into a known inactive state, protecting the power stage outputs. One MΩ resistors R21 and R25 add 20 mV of hysteresis to aid with noise immunity.

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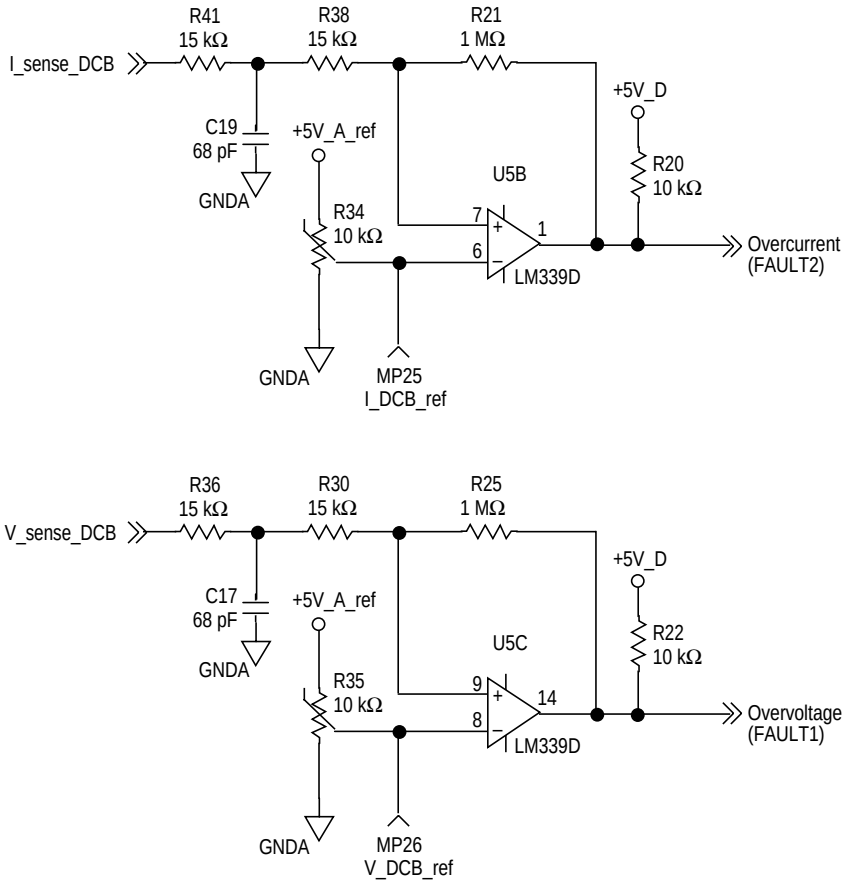

Figure 5-2. Fault Circuits

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5.9 Tachometer Input

One method for measuring motor speed is to use the analog ac output signal from a tachometer connected to the motor's shaft. The conditioned signal then can be carried into a timer interrupt on the MR32. The period between interrupts is used to calculate motor shaft speed. The circuit in **Figure 5-2** is used to "square" the ac signal from the tachometer output into a digital signal acceptable to the timer. The input of this circuit has a threshold of approximately 180 mV. Its input hysteresis is set at approximately 20 mV to aid with noise immunity.

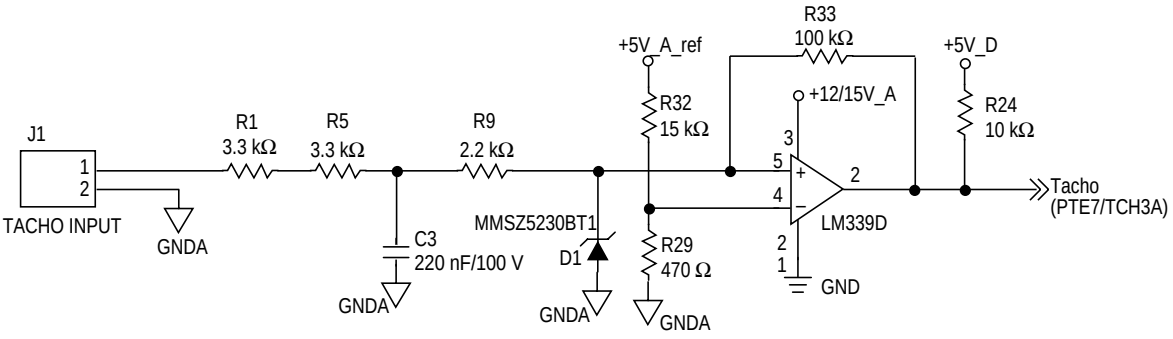

Figure 5-3. Tachometer Input

5.10 Optoisolated RS-232 Interface

RS-232 serial communication is provided by the circuit in **Figure 5-4**. It is optically isolated for safety and is suitable for communication rates up to 9600 baud.

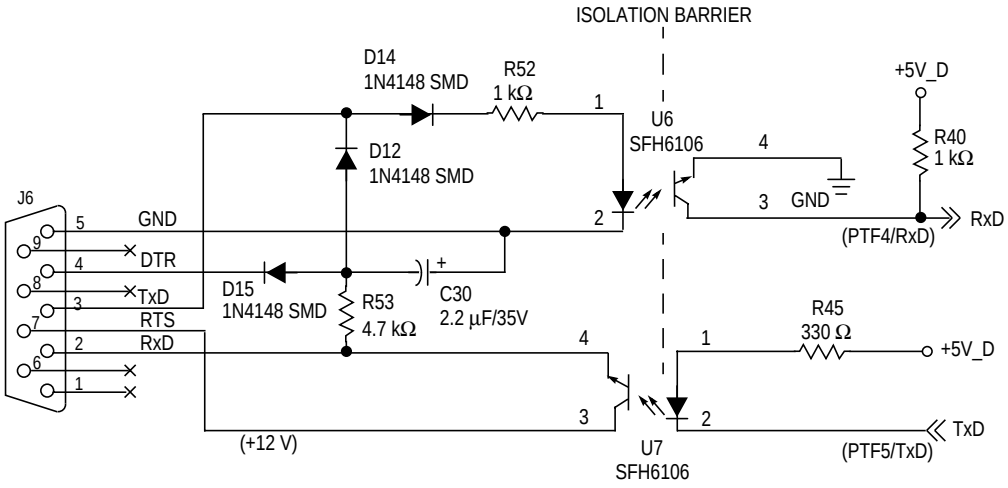

Figure 5-4. RS-232 Interface

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The EIA RS-232 specification states that signal levels can range from ±3 volts to ±25 volts. A mark is defined as a signal that ranges from –3 volts to –25 volts. A space is defined as a signal that ranges from +3 volts to +25 volts. Therefore, to meet the RS-232 specification, signals to and from a terminal must transition through 0 volts as they change from a mark to a space. Breaking the isolated RS-232 circuit into input and output sections makes explanation of the circuit simpler.

Input interface is through opto coupler U6. To send data from a PC through U6, it is necessary to satisfy the SCI input on the MR32. In the idle condition, the SCI input must be at a logic 1. To accomplish that, the transistor in U6 must be off. The idle state of the transmit data line (TXD) on the PC serial port is a mark (–3 V to –25 V). Therefore, the diode in U6 is off and the transistor in U6 is off, yielding a logic 1 to the SCI input. When the start bit is sent to the SCI from the PC's serial port, the PC's TXD transitions from a mark to a space (+3 V to +25 V), forward biasing the diode in U6. Forward biasing the diode in D3 turns on the transistor in U6, providing a logic 0 to the input of the SCI. Simply stated, the input half of the circuit provides input isolation, signal inversion, and level shifting from the PC to the MR32's SCI port. An RS-232 line receiver, such as an MC1489, serves the same purpose without the optoisolation function.

To send data from the MR32 control board to a PC serial port input, it is necessary to satisfy the PC's receive data (RXD) input requirements. In an idle condition, the RXD input to the PC must be at mark (–3 V to –25 V). The data terminal ready output (DTR) on the PC outputs a mark when the port is initialized. The request to send RTS output is set to a space (+3 V to +25 V) when the PC's serial port is initialized. Because the interface is half-duplex, the PC's TXD output is also at a mark, as it is idle. The idle state of the transmit data line (TXD) on the MR32's SCI is a logic 1. The logic 1 out of the SCI's output port forces the diode in U7 to be turned off. With the diode in U7 turned off, the transistor in U7 is also turned off. The junction of D12 and D15 are at a mark (–3 V to –25 V). With the transistor in U7 turned off, the input is pulled to a mark through current limiting resistor R53, satisfying the PC's serial input in an idle condition. When a start bit is sent from the MR32's SCI port to the output of the MR32's SCI, output transitions to a logic 0. That logic 0 turns on the diode in U5, thus turning on the transistor in U7. The conducting transistor in U5 passes the voltage output from the PC's RTS output, that is now at a space (+3 V to +25 V), to the PC's receive data (RXD) input. Capacitor C30 is a bypass capacitor used to "stiffen" the mark signal. The output half of the circuit

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provides output isolation, signal inversion, and level shifting from the MR32's SCI output port to the PC's serial port. Again an RS-232 line driver, such as an MC1488, serves the same purpose without the optoisolation function.

5.11 Back EMF Signals

Back EMF signals are provided for sensorless control of brushless dc motors and dead time distortion correction in ac induction motors. Analog signals BEMF_sense_A, BEMF_sense_B, and BEMF_sense_C are passed directly from connector J5 pins 38, 39, and 40 to A/D inputs ADC7, ADC8, and ADC9. Digital signals Zero_cross_A, Zero_cross_B, and Zero_cross_C are routed to the circuit illustrated in **Figure 5-5**.

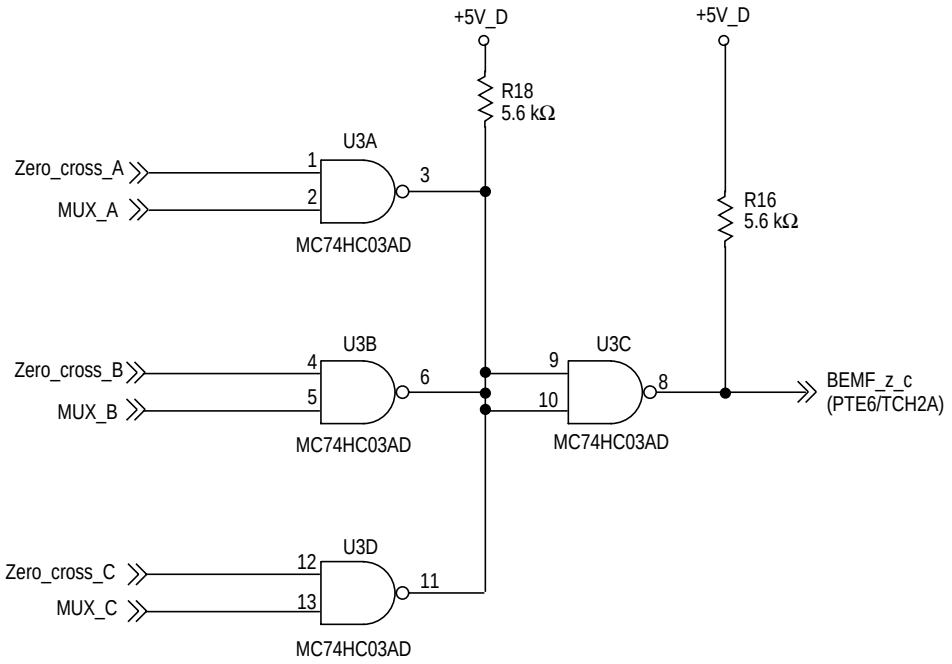

Figure 5-5. Zero Cross Back EMF Circuit

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The back-EMF selection logic in **Figure 5-5** is designed to provide an interrupt to channel 2 of the MR32's timer A input upon each motor phase's zero-crossing. The three open collector NAND gates U3A, U3B, andU3D are wire ORed such that any one of these outputs switching to logic 0 will provide an interrupt to the MR32's timer A input. MUXA, MUXB, and MUXC inputs to the NAND gates enable zero cross signals from each phase to interrupt the processor. During system operation, the software is aware of the window when a zero-crossing interrupt should occur for any given phase. MUXA, MUXB, and MUXC inputs to the NAND gates are enabled for each phase during its computed zero cross window. This technique increases noise robustness by eliminating noise glitches from triggering false interrupts outside of the computed zero cross-windows.

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